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## Abstract

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# CONCENTRATION LIMITS OF FLAME PROPAGATION IN A MIXTURE OF ACETYLENE WITH AIR

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In work (1) it was shown that, at atmospheric pressure, there are no upper concentration limits for flame propagation in mixtures of acetylene with oxygen and air. The erroneous determination of the values of the upper concentration limits was due to the fact that ignition sources of insufficient power were used to initiate the process. The present paper gives the results of a study of the concentration limits of flame propagation in a mixture of acetylene with air at various initial pressures. The experiments were carried out in the apparatus described in work (2). Steel vessels of capacity 2.5 liters (diam. 100 mm) and 6.5 liters (diam. 160 mm) were used in the experiments. Ignition was produced at the end face at a distance equal to the radius of the vessel.

In determining the ignition energy in mixtures of acetylene with air, it was established that, over a wide interval of variation of the acetylene concentration in the mixture, the ignition energy differs little from the values usually determined for other fuel-air mixtures, for example, ethane + air or ethylene + air. However, with a further increase in the acetylene content in the mixture, up to pure acetylene, at initial pressures below 1.4 ata, the ignition energy rises rapidly and, at the limiting initial pressure of pure acetylene, equal to 0.65 ata, reaches a value of 900 J.

It proves impossible in this case to work with a maximum fixed ignition source (in our case 900 J) over the entire measured interval of mixture concentrations and initial pressures, as is usually done in determining concentration limits in mixtures of hydrocarbons with air. This is connected with the fact that the energy of the acetylene-air mixture, beginning with certain values of composition and pressure, in those vessels that could be used under laboratory conditions, becomes comparable with the magnitude of the ignition energy. Therefore the determination of the concentration limits of flame propagation as a function of the initial pressure for acetylene-air mixtures was carried out according to the following scheme. For a fixed mixture composition, the dependence of the ignition energy on the initial pressure in the experiment was determined experimentally. It is known that such a dependence has a plateau, from which the limiting pressure of flame propagation in the mixture of a given composition is

Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

easily determined; and from the point at which the curve passes onto the plateau the limiting, maximum ignition energy is determined, which is usually called the saturating ignition energy. From the limiting pressure values obtained in such experiments one can construct the dependence of the limiting pressure of flame propagation for all mixture compositions, i.e., the concentration limits of flame propagation.

Figure 1 presents the experimental dependence of the ignition energy on the initial pressure in the experiment for pure acetylene and its mixtures with air. The curves shown have a well-defined plateau; i.e., after the ignition energy equal to the saturating value has been reached, a further increase in the energy of the initiating source does not lead to displacement

values of the limiting pressure. Figure 2 shows the dependence of the ignition energy on the composition of an acetylene-air mixture at various initial pressures. Dilution of acetylene with air to 5% practically does not change the ignition energy of the mixture at all the pressures studied. A further increase in the air content in the mixture first leads to an increase in the ignition energy, and then to a decrease, and a mixture with an air content of ~23% has an ignition energy equal to the ignition energy of pure acetylene at the same initial pressure. The curves for different initial pressures are very similar in appearance. The maximum value of the ignition energy is observed everywhere at an air content in the mixture of about 17.5%.

**Fig. 1.** Dependence of the ignition energy (J) on the initial pressure (mm Hg) of an acetylene-air mixture: **1** –85% $C_2H_2$ + 15% air; **2** –90% $C_2H_2$ + 10% air; **3** –pure acetylene; **4** –75% $C_2H_2$ + 25% air; **5** –70% $C_2H_2$ + 30% air; **6** –65% $C_2H_2$ + 35% air; **7** –60% $C_2H_2$ + 40% air; **8** –50% $C_2H_2$ + 50% air; **9** –45% $C_2H_2$ + 55% air; **10** –30% $C_2H_2$ + 70% air ÷ 5% $C_2H_2$ + 95% air.

At an initial pressure of 0.65 ata, i.e., the limiting pressure for flame propagation in pure acetylene, the curve has a discontinuity. This means that at a pressure of 0.65 ata in a mixture with an air content in acetylene from 7 to 23%, flame propagation is impossible. From the graphs it is easy to note that both the limiting pressure for flame propagation and the energy required for ignition at this pressure, beginning with ~23% air, decrease as the air content in the mixture increases.

**Fig. 2.** Dependence of the ignition energy on the composition of an acetylene-air mixture at various initial pressures (ata): **1** –1.0, **2** –0.9, **3** –0.8, **4** –0.7, **5**

Fig. 3. Dependence of the limiting pressure for flame propagation on the composition of an acetylene-air mixture. $T_0 = 18°$

Figure 3: Fig. 3. Dependence of the limiting pressure for flame propagation on the composition of an acetylene-air mixture. $T_0 = 18°$

–0.65, **6** –0.58

At the limiting pressures for pure acetylene the ignition energy is ~900 J, and for a mixture of 70% acetylene and 30% air it is 480 J. The use of ignition sources of such high power naturally requires taking into account their influence on the initial parameters of the mixture. Calculation shows that, with a thermal efficiency of the spark equal to ~15% ($^3$), the increase in pressure in a vessel of 6.5 l capacity for pure acetylene at an initial pressure of 0.65 ata (495 mm Hg), when an ignition source with an energy of 1000 J is used, will be ~25 mm Hg, or 5% of the initial pressure.

In reality, the increase in pressure is still smaller. From the obtained dependences of the ignition energy on the initial pressure of the mixture, it is evident that increasing the ignition energy, compared with the necessary value, even by a factor of 5-6 (Fig. 1), does not lead to any noticeable decrease in the limiting pressure (within the experimental error, which is no greater than 5%).

Using the results of the experiments presented in Fig. 1 and Fig. 2, it is easy to construct the dependence of the limiting initial pressure for flame propagation on the composition of the mixture (Fig. 3). The region lying above the curve is called the ignition region of the mixture, or the region in which flame propagation is possible. The region lying below the curve is called the region of noncombustible mixture compositions. From the graph shown in Fig. 3 it can be seen that, with strong dilution of acetylene by air, the character of the dependence of the limiting initial pressure on the composition of the mixture is very similar to the analogous dependences obtained for other combustible mixtures. For the acetylene-air mixture there also exists a lower concentration limit of flame propagation, which quantitatively coincides with the value usually cited in the literature ($^4$). However, for the acetylene-air mixture there is no upper concentration limit, which is connected with the possibility of flame propagation in pure acetylene down to an initial pressure of 0.65 ata.

**Fig. 3.** Dependence of the limiting pressure for flame propagation on the composition of an acetylene-air mixture. $T_0 = 18°$

Therefore, the left branch of the indicated curve, which has no asymptote, is not characteristic of ordinary mixtures of hydrocarbons with air or oxygen.

It is obvious that a dependence of this kind may be expected for combustible mixtures in which one of the components is a substance similar to acetylene (for example, hydrazine), capable of decomposition through the self-propagation of a zone of chemical reaction (flame) from the point of initiation throughout the entire volume of the substance.

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*Note: Figure translations are in progress. See original paper for figures.*